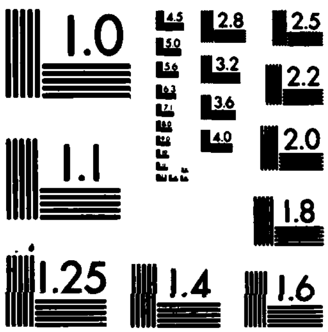
AD-A140 229   PRODUCTION OF PLASMA WITH VARIABLE RADIAL ELECTRIC FIELDS(U) IOWA UNIV IOWA CITY DEPT OF PHYSICS AND ASTRONOMY B KUSTOM ET AL. FE 84 U. OF IOWA-84-3   1/1

UNCLASSIFIED   N00014-83-K-0452   F/G 20/9   NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

U. of Iowa 84-3

PRODUCTION OF PLASMA WITH VARIABLE, RADIAL ELECTRIC FIELDS

by

Brittan Kustom, Robert L. Merlino,
and Nicola D'Angelo

Department of Physics and Astronomy
The University of Iowa
Iowa City, Iowa 52242

ABSTRACT

A device is described suitable for plasma wave experiments requiring relatively large, variable, radial electric fields perpendicular to a static magnetic field. By separately adjusting the potentials of two independent, coaxial discharge plasmas, the authors ~~we have been able to~~ produced plasmas with a radial electric field $E_r \lesssim 5$ V/cm.

= sub r < approx.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER U. of Iowa 84-3	2. GOVT ACCESSION NO. AD-A140229	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Production of Plasma with Variable, Radial Electric Fields		5. TYPE OF REPORT & PERIOD COVERED Progress, February 1984
		6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) Brittan Kustom, Robert L. Merlino, and Nicola D'Angelo		8. CONTRACT OR GRANT NUMBER(s) N00014-83-K-0452
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Physics and Astronomy The University of Iowa Iowa City, Iowa 52242		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS --
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Physics Division Arlington, VA 22217		12. REPORT DATE February 1984
		13. NUMBER OF PAGES 11
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

To be published in Rev. Sci. Instrum.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Radial Electric Fields
Plasma Device
Plasma Instabilities

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A device is described suitable for plasma wave experiments requiring relatively large, variable, radial electric fields perpendicular to a static magnetic field. By separately adjusting the potentials of two independent, coaxial discharge plasmas, we have been able to produce plasmas with a radial electric field $E_r \leqslant 5$ V/cm.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

I. INTRODUCTION

In this paper we describe a method for applying a relatively large ($\lesssim$ 5 V/cm), variable, radial electric field in a cylindrical, argon discharge column. This is an extension of previous work[1] in which radial electric fields, $E_r \approx 0.5$ V/cm were applied in order to study the low-frequency Farley-Buneman instability[2,3] which is driven by a relative $\underset{\sim}{E} \times \underset{\sim}{B}$ drift of electrons and ions on the order of C_s, the ion-acoustic speed. Lee et al.[4] have shown that for higher relative drifts the maximum growth rate of the instability shifts to higher frequencies. In order to study this instability larger radial electric fields, $E_r \gtrsim 1$ V/cm, are required. The ability to vary E_r while keeping the density approximately constant is also desirable.

A laboratory test of the (low-frequency) Farley-Buneman instability was carried out by D'Angelo et al.[5] in a Q-machine. In their setup the usual tantalum hot plate used to ionize the Cs atoms was replaced by a double-wound spiral of 2 mm diameter tantalum wire, with a spiral diameter of 6 cm. The spiral was heated by applying a 5.9 V potential difference between its edge (positive) and its center (negative). With this arrangement an average radial (inward) electric field of ~ 2 V/cm was produced in the plasma.

Although this electric field was sufficient to produce the required $\underset{\sim}{E} \times \underset{\sim}{B}$ drift, it could not be varied, since it was largely determined by the applied heating voltage.

Subsequent experiments on EM backscatter from Farley-Buneman waves by Alport et al.[1] were carried out in a hot filament discharge in argon. In their setup a radial electric field variable from ~ 0 V/cm to ~ 1 V/cm was produced by applying a positive potential to anode rings concentric with the plasma column (cf. Fig. 4 Alport et al.[1]) The average radial electric field tended to increase as the anode voltage, V_A, was increased, but saturated to $E_r \approx 0.5$ V/cm for $V_A \gtrsim 40$ V. A similar arrangement had also been used by John and Saxena[6] and Saxena and John[7] in their observations of the Farley-Buneman instability and the gradient-drift (cross-field) instability. (See Saxena[8] for a review of experiments on these instabilities.)

II. EXPERIMENTAL SETUP

We describe in this section the experimental apparatus and the operation of a device used to produce a plasma with a large, variable, radial electric field.

A schematic of the plasma device is shown in Fig. 1. This setup is a modification of the one used by Alport et al.[1] employing the same vacuum vessel, magnet coils, core plasma filament structure, and anode rings. We have added a cylindrical aluminum can, 30 cm in diameter, which is electrically connected to anode rings A_2 and A_3, and an additional set of filaments (AP, annular plasma radial filament structure) mounted on anode ring A_2. The anode end plate (EP) and ring A_4 are connected to the vacuum chamber which is grounded. Plasma and primary electrons from the discharge chamber (right side) stream through the aperture in anode ring A_4, thus producing a central (or core), CP, plasma (with a diameter determined mainly by the aperture in A_4) which is terminated in the main chamber on the (grounded) end plate attached to A_1. Typically the main discharge (CP) is operated with a background argon pressure of $p \approx 10^{-3}$ Torr, with a discharge current $I_d^{CP} \approx 1 - 4$ A, discharge voltage $V_d^{CP} = 50$ V and at a magnetic field $B = 225$ G in the center of the main chamber. The axial variation of the magnetic field is about 15% over 40 cm.

The annular plasma is produced by a discharge between the AP filaments and anode rings A_2, A_3, and the aluminum can. This discharge is operated at $I_d^{AP} \approx 10$ mA - 15 mA and $V_d^{AP} = 50$ V. The potential of the annular plasma is controlled by varying the anode bias V_A. The power supplies for producing and biasing the annular plasma are independent of those for the central plasma.

The operation of the device described above is similar to that of a standard double-plasma (DP) device.[9] In a DP device two plasmas separately produced in a common vacuum chamber are partially isolated by a negatively biased grid which prevents the two electron species from intermixing. In our setup, which may be described as a coaxial DP device, the axial magnetic field inhibits the mobility of the primary ionizing electrons, their gyroradius being $\approx$ 1 mm.

The radial electric field is produced when the AP anode structure (A_2, A_3) and aluminum can is biased to a potential V_A from 0 V to 20 V. When this potential is applied, the space potential of the annular plasma rises to a value $\gtrsim V_A$. The core plasma anodes A_1 and A_4 are kept at earth potential, and as V_A is increased the CP space potential rises, but by only a small fraction of V_A. The resulting radial profiles of density, n_e, and space potential, V_{sp}, are shown in Fig. 2. The discharge parameters for this case are $I_d^{CP} = 4$ A, $I_d^{AP} = 10.5$ mA, and $V_d^{CP} = V_d^{CP} = 50$ V, with the anode voltage $V_A = 8$ V. Under these conditions a nearly parabolic potential profile is measured as a Langmuir probe is moved across the column over a distance -2.5 cm $< R < +2.5$ cm, with a corresponding average radial electric field, $E_r \approx 1.4$ V/cm. Similar curves are obtained for different V_A's, which show a general increase of the radial electric field with increasing V_A. This is illustrated in Fig. 3, where the difference in space potential, ΔV_{sp}, as measured by a movable Langmuir probe, between R = 5 cm and R = 0 cm, is plotted as a function of V_A. The discharge conditions for Fig. 3 are $I_d^{CP} = 1.8$ A, $I_d^{AP} = 10$ mA with $V_d^{CP} = V_d^{AP} = 50$ V. If the anode voltage V_A is increased above approximately 20 V, the core plasma potential suddenly jumps to a value $V_{sp} \lesssim V_A$, thus resulting in a small value of E_r. The results of Fig. 3 are in contrast to the earlier data of Alport et al.[1] which showed the radial electric field saturating at $E_r \simeq 0.5$ V/cm for $V_A > 30$ V.

III. SUMMARY AND CONCLUSIONS

We have described a device suitable for plasma wave studies requiring relatively large, variable, radial electric fields. By generating a very low density annular plasma surrounding a denser plasma core we are able to impose radial electric fields $E_r \lesssim 5$ V/cm by separately fixing the space potentials of each plasma. This represents roughly a factor of 4-5 improvement in E_r over the setup used by Alport et al.[1]

ACKNOWLEDGMENTS

We thank A. Scheller for his skillful technical assistance. This work was supported by the U.S. Office of Naval Research, contract N00014-83-K-0452 and in part by NASA grant NGL-16-001-043.

REFERENCES

[1]M. J. Alport, N. D'Angelo, and H. L. Pécseli, J. Geophys. Res. 86, 7694 (1981).

[2]D. T. Farley, J. Geophys. Res. 68, 6083 (1963).

[3]O. Buneman, Phys. Rev. Lett. 10, 285 (1963).

[4]K. Lee, C. F. Kennel, and J. M. Kindel, Radio Sci. 6, 209 (1971).

[5]N. D'Angelo, H. L. Pécseli, and P. I. Petersen, J. Geophys. Res. 79, 4747 (1974).

[6]P. I. John and Y. C. Saxena, Geophys. Res. Lett., 2, 251 (1975).

[7]Saxena, Y. C., and P. J. John, Geophys. Res. Lett., 2, 492 (1975).

[8]Yogesh C. Saxena, "Laboratory Experiments Related to Plasma Instabilities in the Electrojets," in Relation between Laboratory and Space Plasmas, edited by H. Kikuchi (D. Reidel, Hingham, Mass., 1981).

[9]R. J. Taylor, K. R. MacKenzie, and H. Ikezi, Rev. Sci. Instrum. 43, 1675 (1972).

FIGURE CAPTIONS

Fig. 1. (a) The experimental setup, showing a topview of the coaxial plasma device. (b) Core plasma and annular plasma filament structures.

Fig. 2. Radial profiles of plasma electron density, n_e, and space potential, V_{sp}. Plasma densities are in the range of $10^9 - 10^{10}$ cm^{-3}.

Fig. 3. Difference in space potential ΔV_{sp}, between R = 0 cm and R = 5 cm as a function of the anode bias voltage V_A .

D-G84-22-2

(a)

(b)

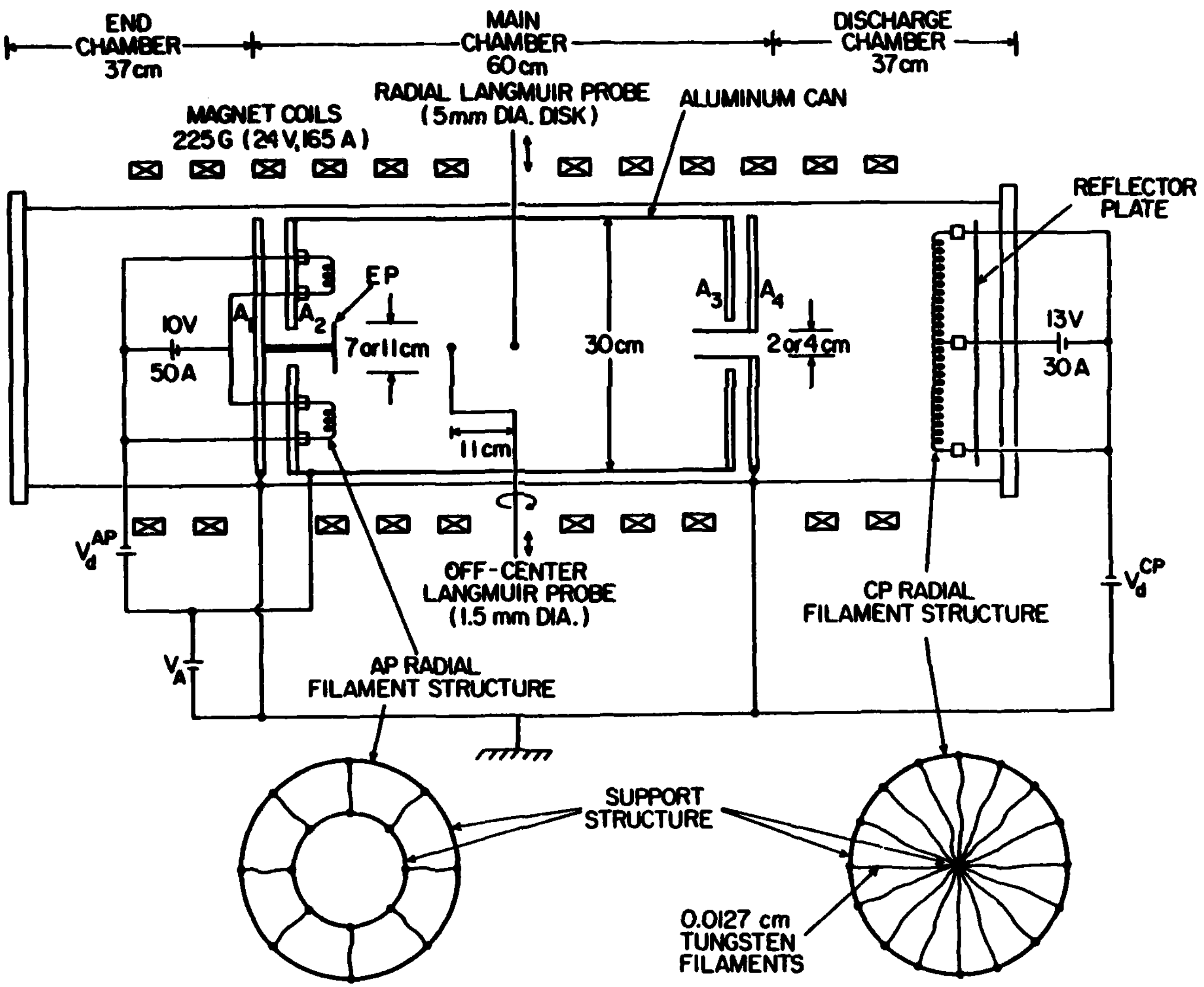
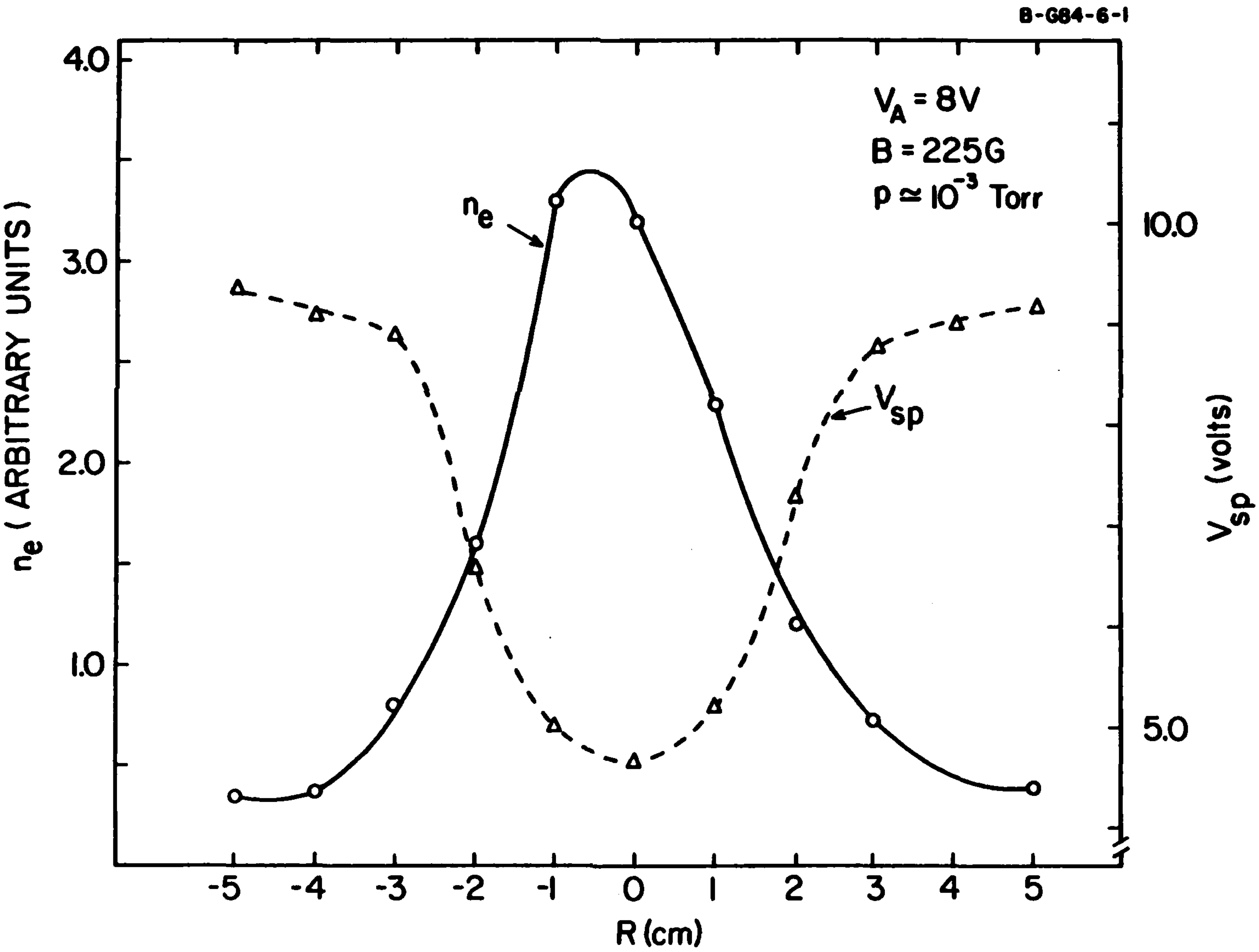


Fig. 1



B-G84-6-1
$V_A = 8V$
$B = 225G$
$p \simeq 10^{-3}$ Torr
n_e
V_{sp}
4.0
3.0
2.0
1.0
n_e (ARBITRARY UNITS)
10.0
5.0
V_{sp} (volts)
-5
-4
-3
-2
-1
0
1
2
3
4
5
R (cm)

Fig. 2

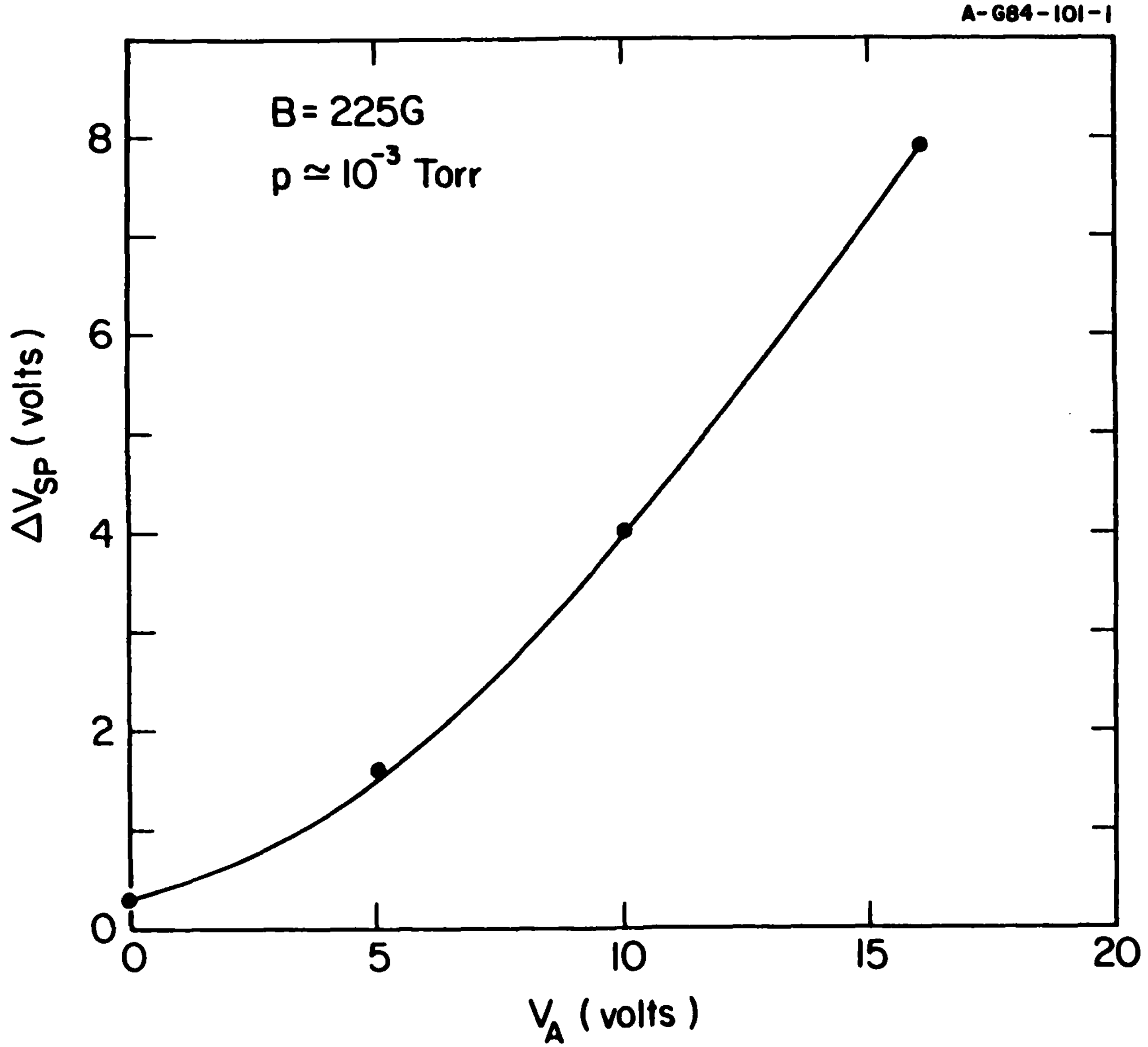

A-G84-101-1
B = 225G
p ≃ 10^-3 Torr
ΔV_SP (volts)
V_A (volts)
0
2
4
6
8
0
5
10
15
20

Fig. 3

END

FILMED

5-84

DTI